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Karyotype Analysis of Six Species of the Genus *Ophiopogon* (Convallariaceae–Ophiopogoneae)

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Ophiopogon brevipes from Doi Suthep, Chiang Mai Prov., Thailand, *O. jaburan* from Isls. Koshikijima and Isl. Kuroshima, Kagoshima Pref., Japan, *O. planiscapus* from Mt. Sanjohgatake, Nara Pref., Japan, and *O. siamensis* from Doi Inthanon, Chiang Mai Prov., Thailand were found to be diploid with $2n = 36$, *O. sylvicola* from Mt. Wawushan, Sichuan, China to be triploid with $2n = 54$, *O. japonicus* var. *japonicus* from Minoo, Osaka Pref., Japan to be hypotetraploid with $2n = 70$, and *O. japonicus* var. *umbrosus* from Yao, Osaka Pref., Japan to be tetraploid with $2n = 72$. *O. brevipes*, *O. siamensis* and *O. sylvicola* were karyologically investigated for the first time in the present study. The chromosome number $2n = 54$ and $2n = 70$ are new counts for the genus. The karyotypes analyzed in the present study are categorized into two groups: Jaburan-group with two pairs of medium-sized chromosomes and Brevipes-group with three pairs of medium-sized chromosomes, although the karyotypes of *O. japonicus* are categorized into neither group. *O. jaburan*, *O. planiscapus*, *O. siamensis* and *O. sylvicola* with karyotypes of the Jaburan-group, are distributed in warm temperate to cool temperate zones. *O. brevipes* with a karyotype of the Brevipes-group, is distributed in a tropical monsoon zone.

Key words: Chromosome number, Convallariaceae, karyotype, Liliaceae sensu lato, *Ophiopogon*

The genus *Ophiopogon* was grouped with *Liriope* and *Peliosanthes* as Convallariaceae–Ophiopogoneae by Dahlgren et al. (1985) and Conran and Tamura (1998), and the grouping was confirmed by both *rbc*L and *trn*K molecular phylogenetic trees (Yamashita and Tamura 2000). The three genera share a unique synapomorphic characteristic: the fruit rupturing in early development, exposing the seeds with a sarcotesta. They share also $x = 18$ basic chromosome number (Tamura 1995). *Ophiopogon* differs from *Liriope* in perigynous actinomorphic flowers, very short filaments, and blue seeds. *Ophiopogon* differs from *Peliosanthes* in longitudinally whitish striped leaves without conspicuous transverse veins, and flowers lacking corona.

Ophiopogon comprises about 55 species, which are distributed in India, the Himalayas, Indochina, Malesia, China and Japan. Among the 55 species, 23 species have been karyologically revealed (Table 1). Chromosome numbers of the remaining about 32 species are still unknown. The purpose of the present study is to accumulate karyological informations of the genus *Ophiopogon* in order to understand more de-

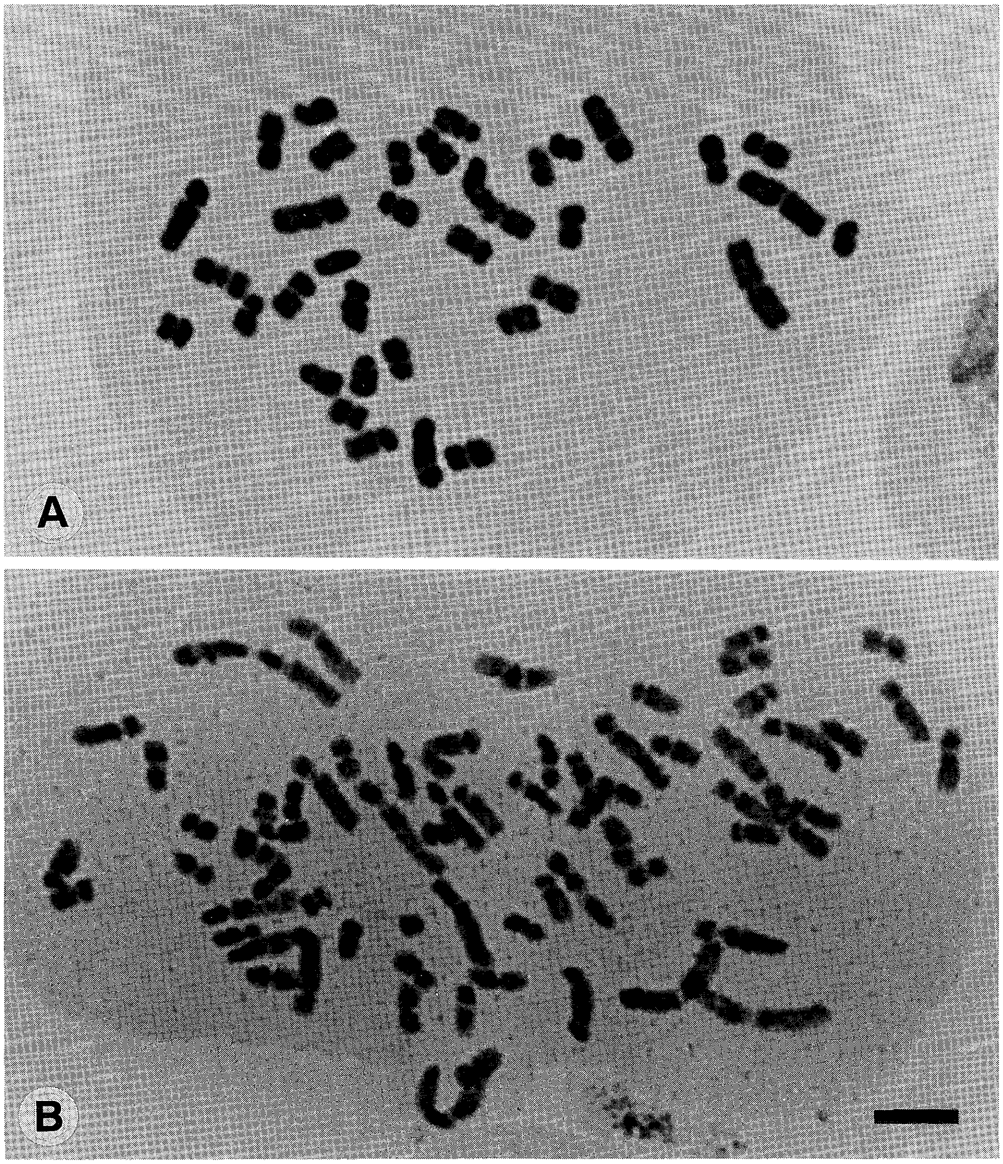


Fig. 1. Somatic metaphase chromosomes of *Ophiopogon* species. A, *O. planiscapus* from Pref. Nara: Mt. Sanjohgatake; B, *O. japonicus* var. *japonicus* from Osaka Pref.: Minoo. Detailed localities are shown in Table 2. Bar = 5 μm.

tailed karyotype diversity of the genus and to establish a basis of more reliable classification of the genus.

Materials and Methods

The sources of materials examined in the present study are given in Table 2. The plants, except for *O. sylvicola*, were collected from their native habitats, transplanted into clay pots, and cultivated in Osaka City University. Root tip preparations were made by using the squash method of Tamura

Table 1. Present and previous karyological studies of the genus *Ophiopogon*

Taxa	Present counts (2n)	Previous counts		References
		(n)	(2n)	
Ophiopogon brevipes Craib	36*			
O. bockianus Diels			36	Yang et al. (1990)
O. bodinieri Leveillé			36	Yang et al. (1990)
O. chingii Wang & Tang			36	Yang et al. (1990)
O. clarkei Hook.f.		19		Sarkar et al. (1974)
			38	Sarkar et al. (1974)
O. dracaenoides (Baker) Hook.f.			36	Yang et al. (1990)
O. griffithii (Baker) Hook.f.			36	Yang et al. (1990)
O. intermedius D.Don.		18		Sachdeva (1987)
(= *O. aciformis* Wang & Tang ex H.Li & Y.P.Yang) (= *O. wallichianus* Hook.f.)			36	Malik (1962), Larsen (1963), Sharma & Chaudhuri (1964), Sarkar et al. (1974), Roy et al. (1988), Yang et al. (1990)
			68	Sen (1973)
			108	Malik (1962), Sheriff & Singh (1975)
			112	Dudgeon (1923)
var. *gracilipes* Hook.f.		54		Vijayavalli & Mathew (1990a, 1990b)
			108	Vijayavalli & Mathew (1990a, 1990b)
var. *pauciflorus* Hook.f.		54		Vijayavalli & Mathew (1990a, 1990b)
			108	Vijayavalli & Mathew (1990a, 1990b)
O. jaburan (Kunth) Lodd.	36		36	Matsuura & Suto (1935), Sato (1942), Hasegawa (1968), Ko et al. (1985)
O. japonicus (L.f.) Ker Gawl.			36	Sato (1942)
(= *O. chekiangensis*			67	Nagamatsu & Noda (1964, 1971)
K.Kimura & H.Migo)			68	Nagamatsu & Noda (1964, 1971), Liu et al. (1985), Ge et al. (1988)
	70*			
			72	Sato (1942), Oinuma (1944, 1946, 1949), Sharma & Chaudhuri (1964), Hasegawa (1968), Hsu (1971), Ko et al. (1985), Liu et al. (1985), Yang et al. (1990)
var. *umbrosus* Maxim.			67	Nagamatsu & Noda (1971)
(= *O. ohwii* Okuyama)			68	Nagamatsu & Noda (1971)
	72		72	Hasegawa (1968), Ko et al. (1985)
O. latifolius L.Rodrig.			36	Yang et al. (1990)
O. malcolmsonii Royle			36	Larsen (1963)
O. marmoratus Pierre ex L.Rodrig.			36	Yang et al. (1990)
O. megalanthus F.T.Wang & L.K.Dai			36	Yang et al. (1990)
O. micranthus Hook. f.			108	Malik (1961, 1962)
O. peliosanthoides Wang & Tang			36	Yang et al. (1990)
O. pingbienensis F.T.Wang & L.K.Dai			36	Yang et al. (1990)
O. planiscapus Nakai		18		Oinuma (1944), Hsu (1971)
	36		36	Oinuma (1946, 1949), Hasegawa (1968), Hsu (1971)
			72	Sato (1942), Oinuma (1944, 1946, 1949)
O. reptans Hook.f.			36	Larsen (1963)
O. revolutus F.T.Wang & L.K.Dai			36	Yang et al. (1990)
O. siamensis M.N.Tamura	36*			
O. stenophyllus (Merrill) L.Rodrig.			36	Yang et al. (1990)
O. sylvicola Wang & Tang	54*			
O. tonkinesis L.Rodrig.			36	Yang et al. (1990)
O. tsaii Wang & Tang			36	Yang et al. (1990)
O. xylorrhizus F.T.Wang & L.K.Dai			36	Yang et al. (1990), Ding et al. (1993)**

*These numbers were first counted.

**They may be misspelled *O. xylorrhizus* as *O. sylorrhizus*.

Table 2. Sources of materials

Taxa	Localities	Voucher specimens
Ophiopogon brevipes	Thailand: Doi Suthep, Prov. Chiang Mai, N, 520 m alt.	M. N. Tamura, J. Yamashita & K. Sri-Ngernyuang 6004
O. jaburan	Japan: Mt. Odake, Isls. Koshikijima, Pref. Kagoshima, 530 m alt.	M. N. Tamura & J. Yamashita 9905
	Japan: Mt. Yaguradake, Isl. Kuroshima, Pref. Kagoshima, 400 m alt.	J. Yamashita 3176
O. japonicus var. *japonicus*	Japan: Minoo, Pref. Osaka, 290 m alt.	J. Yamashita 3183
O. japonicus var. *umbrosus*	Japan: Yao, Pref. Osaka, 80 m alt.	J. Yamashita 3016
O. planiscapus	Japan: Mt. Sanjohgatake, Pref. Nara, 520 m alt.	J. Yamashita 3291
O. siamensis	Thailand: Doi Inthanon, Prov. Chiang Mai, N, 1690 m alt.	M. N. Tamura & J. Yamashita 6007
O. sylvicola	China: Mt. Wawushan, Hongya, Sichuan, 2400 m alt.	M. N. Tamura, J. Yamashita, Y. F. Yuan, C. L. Liu, P. L. Wang & F. D. Pu 8658

(1990). As for *O. sylvicola*, root tips were excised in the native habitat, and prepared according to the option for Chinese plants of Tamura (1993). Nomenclature for centromeric position on chromosomes follows Levan et al. (1964). Voucher specimens are preserved in KYO.

Results

Karyological characteristics of the six species and two varieties of the genus *Ophiopogon* examined are as follows.

1. *Ophiopogon brevipes* Craib (Figs. 2, 6, Table 3)

The chromosome number of *O. brevipes* is 2n = 36. The karyotype is composed of one pair of long chromosomes (ca. 4.8 μm in length), three pairs of medium-sized chromosomes (ca. 3.7 μm – ca. 3.9 μm) and 14 pairs of short chromosomes (ca. 2.3 μm – ca. 3.2 μm). The pair of long chromosomes has centromeres at the median region. Among the three pairs of medium-sized chromosomes, two pairs have centromeres at the median region, and the other has centromeres at the submedian region. Among the 14 pairs of short chromosomes, 13 pairs have centromeres at the median region, and the other has centromeres at the submedian region. One pair of short chromosomes with median centromeres (the 9th pair) has secondary constrictions at the central region of the short arms. This plant can be regarded karyologically to be diploid with x = 18 basic chromosome number.

2. *Ophiopogon jaburan* (Kunth) Lodd. (Figs. 2, 6, Tables 4, 5)

Plants collected from two localities, i. e., Isls. Koshikijima and Isl. Kuroshima in Kagoshima Pref., were examined. They have the same chromosome number of 2n = 36 and similar karyotypes. Each karyotype is composed of one pair of long chromosomes (ca. 8.8 μm), two pairs of medium-sized chromosomes (ca. 5.7 μm – ca. 5.9 μm) and 15 pairs of short chromosomes (ca. 2.3 μm – ca. 4.3 μm). The pair of long chromosomes has centromeres at the median region, and the two pairs of medium-sized chromosomes have centromeres at the submedian region. Among the 15 pairs of short chromosomes, one pair (the 6th pair) has centromeres at the subterminal region, and

Table 3. Measurements of somatic metaphase chromosomes of *Ophiopogon brevipes* from Thailand: Doi Suthep. The detailed locality is shown in Table 2. m, sm and st indicate chromosomes with the centromere in the median, submedian and subterminal regions, respectively

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	2.3+2.5	4.8	L	1.1	m
	2.3+2.5	4.8	L	1.1	m
2	1.5+2.4	3.9	M	1.6	m
	1.5+2.4	3.9	M	1.6	m
3	1.3+2.4	3.7	M	1.8	sm
	1.4+2.4	3.8	M	1.7	sm
4	1.7+2.1	3.8	M	1.2	m
	1.6+2.0	3.6	M	1.3	m
5	1.3+2.1	3.4	S	1.6	m
	1.3+1.7	3.0	S	1.3	m
6	1.5+1.7	3.2	S	1.1	m
	1.5+1.7	3.2	S	1.1	m
7	1.5+1.6	3.1	S	1.1	m
	1.5+1.6	3.1	S	1.1	m
8	1.3+1.7	3.0	S	1.3	m
	1.2+1.8	3.0	S	1.5	m
9	(0.7+0.6)+1.8	3.1	S	1.4	m
	(0.6+0.6)+1.6	2.8	S	1.3	m
10	1.3+1.6	2.9	S	1.2	m
	1.2+1.6	2.8	S	1.3	m
11	0.9+2.0	2.9	S	2.2	sm
	1.0+1.7	2.7	S	1.7	sm
12	1.2+1.6	2.8	S	1.3	m
	1.1+1.7	2.8	S	1.5	m
13	1.2+1.4	2.6	S	1.2	m
	1.2+1.5	2.7	S	1.3	m
14	1.3+1.4	2.7	S	1.1	m
	1.2+1.4	2.6	S	1.2	m
15	1.2+1.4	2.6	S	1.2	m
	1.2+1.4	2.6	S	1.2	m
16	1.2+1.4	2.6	S	1.2	m
	1.2+1.4	2.6	S	1.2	m
17	1.2+1.4	2.6	S	1.2	m
	1.2+1.4	2.6	S	1.2	m
18	1.0+1.3	2.3	S	1.3	m
	1.0+1.2	2.2	S	1.2	m

the others have centromeres at the median or submedian region. One pair of short chromosomes with median centromeres (the 10th pair) has secondary constrictions at the proximal region of the short arms. These plants can be regarded to be diploid based on x = 18.

3. *Ophiopogon japonicus* var. *japonicus* (L.f.) Ker Gawl. (Figs. 1, 3, 6, Tables 6, 7)

Different two cells of the same individual collected from Minoo, Osaka Pref. were examined. The chromosome numbers of the

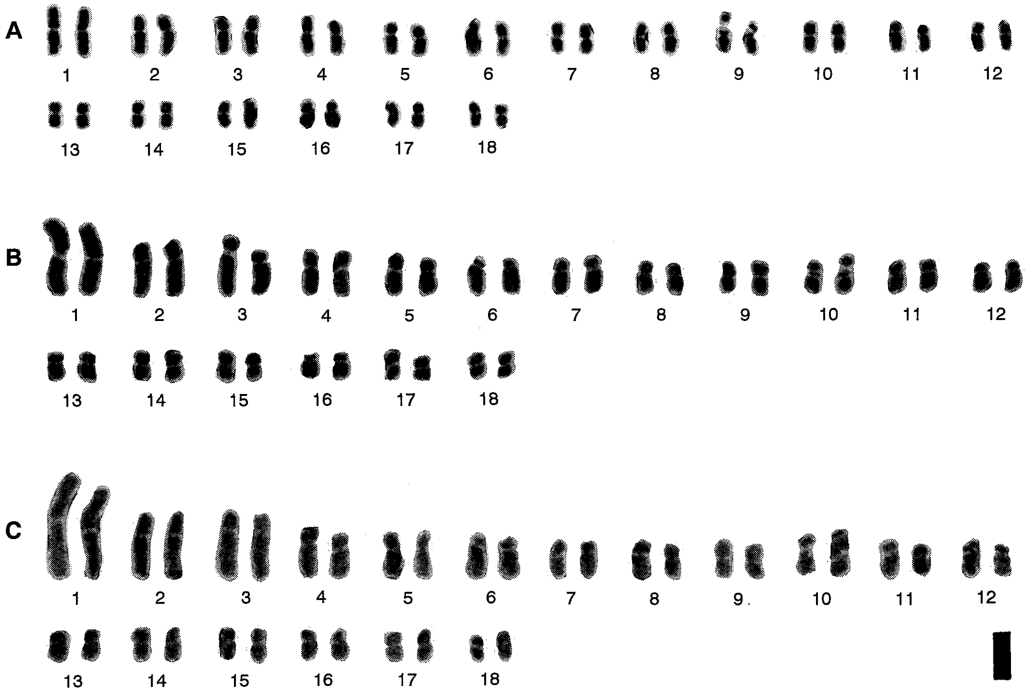


Fig. 2. Serial arrangements of somatic metaphase chromosomes of *Ophiopogon* species. A, *O. brevipes* from Thailand, Doi Suthep; B, *O. jaburan* from Kagoshima Pref., Isls. Koshikijima; C, *O. jaburan* from Kagoshima Pref., Isl. Kuroshima. Detailed localities are shown in Table 2. Bar = 5 μm.

both cells are identical, 2n = 70. The karyotype is composed of two pairs of long chromosomes (ca. 7.4 μm – ca. 8.8 μm), five pairs of medium-sized chromosomes (ca. 4.9 μm – ca. 5.9 μm) and 28 pairs of short chromosomes (ca. 1.5 μm – ca. 4.5 μm). The two pairs of long chromosomes have centromeres at the median region. Among the five pairs of medium-sized chromosomes, two pairs have centromeres at the submedian region, and the others have centromeres at the subterminal region. Among the 28 pairs of short chromosomes, 14 pairs have centromeres at the median region, most of the remaining 14 pairs have centromeres at the submedian region, and a few pairs have centromeres at the subterminal region. One pair of short chromosomes with submedian centromeres (the 9th pair) has secondary constrictions at the proximal region of the long arms. This plant can be regarded karyologically to be hypotetraploid based on x = 18.

4. *Ophiopogon japonicus* var. *umbrosus* Maxim. (Figs. 4, 6, Table 8)

Chromosome number of the plant examined is 2n = 72. The karyotype is composed of one pair of long chromosomes (ca. 8.1 μm), five pairs of medium-sized chromosomes (ca. 3.7 μm – ca. 5.2 μm) and 30 pairs of short chromosomes (ca. 1.4 μm – ca. 3.4 μm). The pair of long chromosomes has centromeres at the median region. Among the five pairs of medium-sized chromosomes, one pair has centromeres at the median region, other three pairs have centromeres at the submedian region, and the remaining one pair has centromeres at the

Table 4. Measurements of somatic metaphase chromosomes of *Ophiopogon jaburan* from Kagoshima Pref., Isl. Koshikijima

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	3.8+4.0	7.8	L	1.1	m
	3.5+3.7	7.2	L	1.1	m
2	1.7+3.6	5.3	M	2.1	sm
	1.7+3.6	5.3	M	2.1	sm
3	1.4+4.1	5.5	M	2.9	sm
	1.2+3.3	4.5	M	2.8	sm
4	1.5+2.7	4.2	S	1.8	sm
	1.5+2.6	4.1	S	1.7	sm
5	1.5+2.5	4.0	S	1.7	sm
	1.2+2.4	3.6	S	2.0	sm
6	0.5+2.8	3.3	S	5.6	st
	0.7+2.6	3.3	S	3.7	st
7	0.9+2.2	3.1	S	2.4	sm
	1.0+2.3	3.3	S	2.3	sm
8	1.3+1.9	3.2	S	1.5	m
	1.2+1.7	2.9	S	1.4	m
9	1.4+1.5	2.9	S	1.1	m
	1.4+1.6	3.0	S	1.1	m
10	(0.9+0.4)+1.6	2.9	S	1.2	m
	(0.9+0.5)+1.5	2.9	S	1.1	m
11	1.0+1.7	2.7	S	1.7	sm
	1.0+1.8	2.8	S	1.8	sm
12	0.7+1.9	2.6	S	2.7	sm
	0.7+2.0	2.7	S	2.9	sm
13	0.9+1.7	2.6	S	1.9	sm
	1.0+1.7	2.7	S	1.7	sm
14	1.3+1.4	2.7	S	1.1	m
	1.2+1.4	2.6	S	1.2	m
15	1.2+1.4	2.6	S	1.2	m
	1.2+1.3	2.5	S	1.1	m
16	0.7+1.8	2.5	S	2.6	sm
	0.8+1.8	2.6	S	2.3	sm
17	1.2+1.3	2.5	S	1.1	m
	1.1+1.3	2.4	S	1.2	m
18	1.1+1.2	2.3	S	1.1	m
	1.1+1.2	2.3	S	1.1	m

subterminal region. Among the 30 pairs of short chromosomes, 16 pairs have centromeres at the median region, other 12 pairs have centromeres at the submedian region, and the remaining two pairs have centromeres at the subterminal region. One pair of short chromosomes with submedian centromeres (the 9th pair) has secondary constrictions at the proximal region of the long arms. This plant can be regarded as a tetraploid with x = 18 basic chromosome number.

5. *Ophiopogon planiscapus* Nakai (Figs. 1, 4, 6, Table 9)

Chromosome number of the plant examined is 2n = 36. The karyotype is composed

Table 5. Measurements of somatic metaphase chromosomes of *Ophiopogon jaburan* from Kagoshima Pref., Isl. Kuroshima

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	5.0+5.7	10.7	L	1.1	m
	4.5+5.0	9.5	L	1.1	m
2	2.2+4.2	6.4	M	1.9	sm
	2.3+4.3	6.6	M	1.9	sm
3	1.7+4.7	6.4	M	2.8	sm
	1.7+4.7	6.4	M	2.8	sm
4	1.6+3.1	4.7	S	1.9	sm
	1.3+2.8	4.1	S	2.2	sm
5	1.7+2.5	4.2	S	1.5	m
	1.7+2.7	4.4	S	1.6	m
6	0.8+3.3	4.1	S	4.1	st
	0.9+2.8	3.7	S	3.1	st
7	1.3+2.2	3.5	S	1.7	sm
	1.1+2.5	3.6	S	2.3	sm
8	1.3+2.0	3.3	S	1.5	m
	1.4+1.9	3.3	S	1.4	m
9	1.5+1.7	3.2	S	1.1	m
	1.5+1.7	3.2	S	1.1	m
10	(0.8+0.7)+1.7	3.2	S	1.1	m
	(0.7+0.5)+1.7	2.9	S	1.4	m
11	1.1+2.1	3.2	S	1.9	sm
	1.0+1.8	2.8	S	1.8	sm
12	0.8+2.3	3.1	S	2.9	sm
	0.8+2.2	3.0	S	2.8	sm
13	1.2+1.9	3.1	S	1.6	m
	1.2+1.8	3.0	S	1.5	m
14	1.4+1.6	3.0	S	1.1	m
	1.4+1.7	3.1	S	1.2	m
15	1.3+1.6	2.9	S	1.2	m
	1.4+1.6	3.0	S	1.1	m
16	1.1+1.7	2.8	S	1.5	m
	1.1+1.7	2.8	S	1.5	m
17	1.2+1.4	2.6	S	1.2	m
	1.3+1.4	2.7	S	1.1	m
18	0.9+1.2	2.1	S	1.3	m
	1.1+1.4	2.5	S	1.3	m

of one pair of long chromosomes (ca. 5.6 μm), two pairs of medium-sized chromosomes (ca. 4.1 μm – ca. 4.3 μm) and 15 pairs of short chromosomes (ca. 2.0 μm – ca. 3.1 μm). The pair of long chromosomes has centromeres at the median region. The two pairs of medium-sized chromosomes have centromeres at the submedian region. Among the 15 pairs of short chromosomes, 10 pairs have centromeres at the median region, and the others have centromeres at the submedian region. One pair of short chromosomes with median centromeres (the 7th pair) has secondary constrictions at the proximal region of the long arms. This plant can be regarded as a diploid based on x = 18.

Table 6. Measurements of somatic metaphase chromosomes of *Ophiopogon japonicus* var. *japonicus* from Osaka Pref., Minoo

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	4.2+5.4	9.6	L	1.3	m
	4.4+4.7	9.1	L	1.1	m
2	3.5+3.8	7.3	L	1.1	m
	3.7+4.6	8.3	L	1.2	m
3	1.8+4.2	6.0	M	2.3	sm
	1.8+4.1	5.9	M	2.3	sm
4	1.2+4.4	5.6	M	3.7	st
	1.7+5.2	6.9	M	3.1	st
5	1.2+4.2	5.4	M	3.5	st
	1.3+4.0	5.3	M	3.1	st
6	1.7+3.8	5.5	M	2.2	sm
	1.8+3.4	5.2	M	1.9	sm
7	1.2+4.0	5.2	M	3.3	st
	1.1+3.8	4.9	M	3.5	st
8	1.3+3.4	4.7	S	2.6	sm
	1.0+3.7	4.7	S	3.7	st
9	1.4+(1.3+2.3)	5.0	S	2.6	sm
	1.4+(0.9+2.1)	4.4	S	2.1	sm
10	1.2+3.5	4.7	S	2.9	sm
	1.0+2.9	3.9	S	2.9	sm
11	1.2+2.9	4.1	S	2.4	sm
	1.0+2.7	3.7	S	2.7	sm
12	1.3+2.3	3.6	S	1.8	sm
	1.0+2.2	3.2	S	2.2	sm
13	0.8+2.6	3.4	S	3.3	st
	0.7+2.5	3.2	S	3.6	st
14	0.8+2.3	3.1	S	2.9	sm
	1.1+2.0	3.1	S	1.8	sm
15	1.5+1.6	3.1	S	1.1	m
	1.4+1.6	3.0	S	1.1	m
16	1.4+1.6	3.0	S	1.1	m
	1.4+1.5	2.9	S	1.1	m
17	1.1+1.8	2.9	S	1.6	m
	1.3+1.7	3.0	S	1.3	m
18	0.9+1.8	2.7	S	2.0	sm
	1.0+1.9	2.9	S	1.9	sm
19	0.7+2.1	2.8	S	3.0	st
	0.6+2.2	2.8	S	3.7	st
20	1.2+1.6	2.8	S	1.3	m
	1.1+1.7	2.8	S	1.5	m
21	1.3+1.5	2.8	S	1.2	m
	1.3+1.5	2.8	S	1.2	m
22	0.8+1.9	2.7	S	2.4	sm
	0.9+1.9	2.8	S	2.1	sm
23	0.9+1.9	2.8	S	2.1	sm
	0.9+1.8	2.7	S	2.0	sm
24	1.1+1.6	2.7	S	1.5	m
	1.1+1.6	2.7	S	1.5	m
25	0.7+1.8	2.5	S	2.6	sm
	0.9+1.7	2.6	S	1.9	sm
26	0.9+1.7	2.6	S	1.9	sm
	0.8+1.6	2.4	S	2.0	sm
27	1.0+1.5	2.5	S	1.5	m
	1.0+1.6	2.6	S	1.6	m
28	1.2+1.4	2.6	S	1.2	m
	1.2+1.4	2.6	S	1.2	m
29	1.2+1.3	2.5	S	1.1	m
	1.2+1.3	2.5	S	1.1	m
30	1.0+1.1	2.1	S	1.1	m
	1.0+1.1	2.1	S	1.1	m
31	0.9+1.1	2.0	S	1.2	m
	1.0+1.1	2.1	S	1.1	m
32	0.9+1.2	2.1	S	1.3	m
	0.8+1.3	2.1	S	1.6	m
33	0.8+1.3	2.1	S	1.6	m
	0.7+1.1	1.8	S	1.6	m
34	0.5+1.0	1.5	S	2.0	sm
	0.6+1.0	1.6	S	1.7	sm
35	0.7+0.8	1.5	S	1.1	m
	0.6+0.8	1.4	S	1.3	m

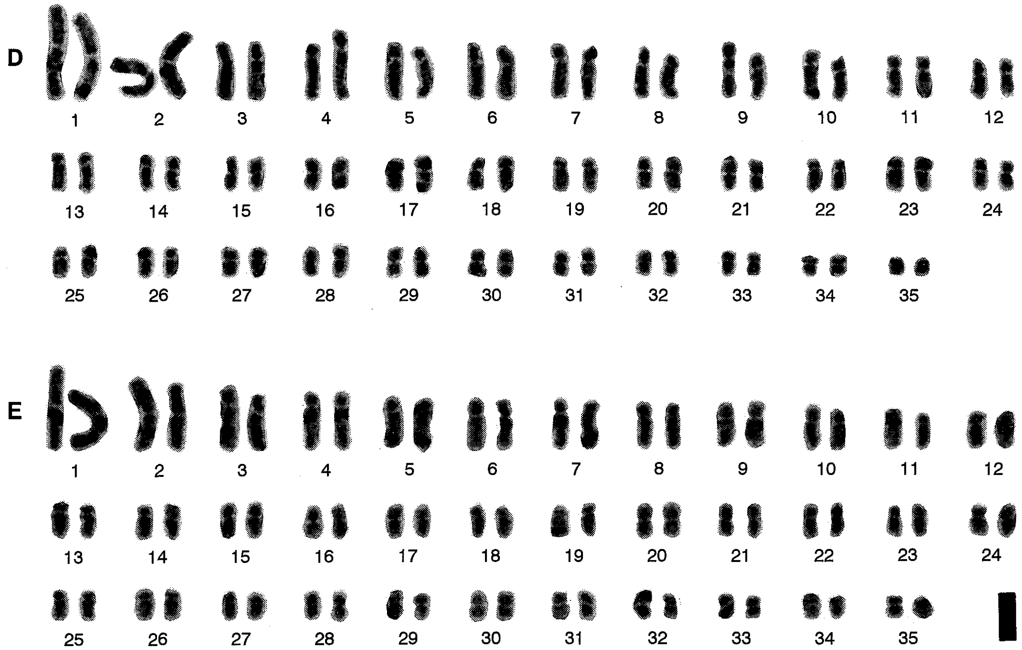


Fig. 3. Serial arrangements of somatic metaphase chromosomes of *Ophiopogon* species. D, E. *O. japonicus* var. *japonicus* from Osaka Pref., Minoo (D and E were obtained from the different cells of the same individual). Bar = 5 μm.

6. *Ophiopogon siamensis* M.N.Tamura (Figs. 5, 6, Table 10)

The chromosome number of *O. siamensis* is 2n = 36. The karyotype is composed of one pair of long chromosomes (ca. 8.2 μm), two pairs of medium-sized chromosomes (ca. 5.5 μm – ca. 6.1 μm) and 15 pairs of short chromosomes (ca. 2.4 μm – ca. 4.8 μm). The pair of long chromosomes has centromeres at the median region. The two pairs of medium-sized chromosomes have centromeres at the submedian region. Among the 15 pairs of short chromosomes, nine pairs have centromeres at the median region, and the others have centromeres at the submedian region. This plant can be regarded as a diploid based on x = 18.

7. *Ophiopogon sylvicola* Wang & Tang (Figs. 5, 6, Table 11)

Chromosome number of the plant examined is 2n = 54. The karyotype is composed of one pair of long chromosomes (ca. 7.3 μm), two pairs of medium-sized chromosomes (ca. 5.1 μm – ca. 5.3 μm) and 15 pairs of short chromosomes (ca. 1.9 μm – ca. 3.8 μm). The pair of long chromosomes has centromeres at the median region. The two pairs of medium-sized chromosomes have centromeres at the submedian region. Among the 15 pairs of short chromosomes, nine pairs have centromeres at the median region, and the others have centromeres at the submedian region. One pair of short chromosomes with submedian centromeres (the 4th pair) has secondary constrictions at the proximal region of the long arms. This plant can be regarded karyologically to be triploid based on x = 18.

Table 7. Measurements of somatic metaphase chromosomes of *Ophiopogon japonicus* var. *japonicus* from Osaka Pref., Minoo (from the different cell of the same individual as Table 6)

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	3.8+4.4	8.2	L	1.2	m
	3.4+4.8	8.2	L	1.4	m
2	3.6+3.8	7.4	L	1.1	m
	3.0+3.4	6.4	L	1.1	m
3	1.6+4.5	6.1	M	2.8	sm
	1.6+3.8	5.4	M	2.4	sm
4	1.1+4.5	5.6	M	4.1	st
	1.2+4.4	5.6	M	3.7	st
5	1.3+3.9	5.2	M	3.0	st
	1.0+4.0	5.0	M	4.0	st
6	1.8+3.3	5.1	M	1.8	sm
	1.7+3.2	4.9	M	1.9	sm
7	1.1+3.6	4.7	M	3.3	st
	0.9+3.9	4.8	M	4.3	st
8	1.3+2.9	4.2	S	2.2	sm
	1.2+3.1	4.3	S	2.6	sm
9	1.3+(1.0+1.8)	4.1	S	2.2	sm
	1.3+(0.9+1.8)	4.0	S	2.1	sm
10	1.5+2.7	4.2	S	1.8	sm
	1.3+2.6	3.9	S	2.0	sm
11	1.0+2.8	3.8	S	2.8	sm
	0.9+2.4	3.3	S	2.7	sm
12	1.0+2.4	3.4	S	2.4	sm
	1.0+2.3	3.3	S	2.3	sm
13	0.8+2.4	3.2	S	3.0	st
	0.8+2.4	3.2	S	3.0	st
14	0.9+2.3	3.2	S	2.6	sm
	1.0+2.0	3.0	S	2.0	sm
15	1.3+1.8	3.1	S	1.4	m
	1.2+1.9	3.1	S	1.6	m
16	1.4+1.5	2.9	S	1.1	m
	1.4+1.6	3.0	S	1.1	m
17	1.3+1.7	3.0	S	1.3	m
	1.2+1.5	2.7	S	1.3	m
18	0.8+2.0	2.8	S	2.5	sm
	0.9+1.9	2.8	S	2.1	sm
19	0.6+2.0	2.6	S	3.3	st
	0.7+2.1	2.8	S	3.0	st
20	1.2+1.5	2.7	S	1.3	m
	1.3+1.5	2.8	S	1.2	m
21	1.3+1.4	2.7	S	1.1	m
	1.2+1.6	2.8	S	1.3	m
22	0.9+1.8	2.7	S	2.0	sm
	1.0+1.8	2.8	S	1.8	sm
23	1.0+1.7	2.7	S	1.7	sm
	1.0+1.8	2.8	S	1.8	sm
24	1.0+1.6	2.6	S	1.6	m
	1.0+1.6	2.6	S	1.6	m
25	0.8+1.7	2.5	S	2.1	sm
	0.7+1.8	2.5	S	2.6	sm
26	0.8+1.6	2.4	S	2.0	sm
	0.6+1.7	2.3	S	2.8	sm
27	1.0+1.3	2.3	S	1.3	m
	0.9+1.3	2.2	S	1.4	m
28	1.1+1.2	2.3	S	1.1	m
	1.1+1.2	2.3	S	1.1	m
29	1.0+1.2	2.2	S	1.2	m
	1.0+1.2	2.2	S	1.2	m
30	1.0+1.2	2.2	S	1.2	m
	1.0+1.2	2.2	S	1.2	m
31	1.0+1.1	2.1	S	1.1	m
	0.9+1.3	2.2	S	1.4	m
32	0.8+1.3	2.1	S	1.6	m
	0.8+1.2	2.0	S	1.5	m
33	0.9+1.0	1.9	S	1.1	m
	0.9+1.0	1.9	S	1.1	m
34	0.6+1.2	1.8	S	2.0	sm
	0.5+1.1	1.6	S	2.2	sm
35	0.7+1.0	1.7	S	1.4	m
	0.6+0.9	1.5	S	1.5	m

Table 8. Measurements of somatic metaphase chromosomes of *Ophiopogon japonicus* var. *umbrosus* from Osaka Pref., Yao

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	4.0+4.5	8.5	L	1.1	m
	3.2+4.5	7.7	L	1.4	m
2	2.6+2.8	5.4	M	1.1	m
	2.4+2.6	5.0	M	1.1	m
3	1.0+3.8	4.8	M	3.8	st
	1.2+3.7	4.9	M	3.1	st
4	1.4+3.4	4.8	M	2.4	sm
	1.1+3.1	4.2	M	2.8	sm
5	1.0+2.8	3.8	M	2.8	sm
	1.2+3.0	4.2	M	2.5	sm
6	1.0+2.6	3.6	M	2.6	sm
	1.3+2.5	3.8	M	1.9	sm
7	1.1+2.3	3.4	S	2.1	sm
	1.2+2.1	3.3	S	1.8	sm
8	0.8+2.3	3.1	S	2.9	sm
	0.8+2.3	3.1	S	2.9	sm
9	0.8+(0.6+1.5)	2.9	S	2.6	sm
	0.9+(0.5+1.2)	2.6	S	1.9	sm
10	0.9+2.0	2.9	S	2.2	sm
	0.9+1.9	2.8	S	2.1	sm
11	0.6+2.3	2.9	S	3.8	st
	0.6+1.8	2.4	S	3.0	st
12	0.9+2.0	2.9	S	2.2	sm
	0.8+1.9	2.7	S	2.4	sm
13	1.0+1.8	2.8	S	1.8	sm
	1.0+1.8	2.8	S	1.8	sm
14	0.9+1.8	2.7	S	2.0	sm
	1.0+1.7	2.7	S	1.7	sm
15	0.6+2.0	2.6	S	3.3	st
	0.6+2.1	2.7	S	3.5	st
16	0.7+1.9	2.6	S	2.7	sm
	0.8+1.9	2.7	S	2.4	sm
17	0.8+1.9	2.7	S	2.4	sm
	0.8+1.8	2.6	S	2.3	sm
18	1.2+1.3	2.5	S	1.1	m
	1.3+1.4	2.7	S	1.1	m
19	0.7+1.8	2.5	S	2.6	sm
	0.8+1.8	2.6	S	2.3	sm
20	1.1+1.4	2.5	S	1.3	m
	1.1+1.5	2.6	S	1.4	m
21	1.1+1.4	2.5	S	1.3	m
	1.1+1.4	2.5	S	1.3	m
22	0.9+1.4	2.3	S	1.6	m
	1.0+1.5	2.5	S	1.5	m
23	1.0+1.4	2.4	S	1.4	m
	1.0+1.3	2.3	S	1.3	m
24	0.8+1.4	2.2	S	1.8	sm
	0.8+1.6	2.4	S	2.0	sm
25	1.0+1.1	2.1	S	1.1	m
	1.0+1.1	2.1	S	1.1	m
26	1.0+1.1	2.1	S	1.1	m
	1.0+1.1	2.1	S	1.1	m
27	0.8+1.2	2.0	S	1.5	m
	0.8+1.1	1.9	S	1.4	m
28	0.6+1.2	1.8	S	2.0	sm
	0.6+1.4	2.0	S	2.3	sm
29	0.8+1.1	1.9	S	1.4	m
	0.8+1.1	1.9	S	1.4	m
30	0.9+1.0	1.9	S	1.1	m
	0.9+1.0	1.9	S	1.1	m
31	0.9+1.0	1.9	S	1.1	m
	0.9+1.0	1.9	S	1.1	m
32	0.8+1.0	1.8	S	1.3	m
	0.9+1.0	1.9	S	1.1	m
33	0.8+0.9	1.7	S	1.1	m
	0.8+1.0	1.8	S	1.3	m
34	0.7+0.9	1.6	S	1.3	m
	0.7+0.9	1.6	S	1.3	m
35	0.7+0.9	1.6	S	1.3	m
	0.7+0.9	1.6	S	1.3	m
36	0.7+0.8	1.5	S	1.1	m
	0.6+0.7	1.3	S	1.2	m

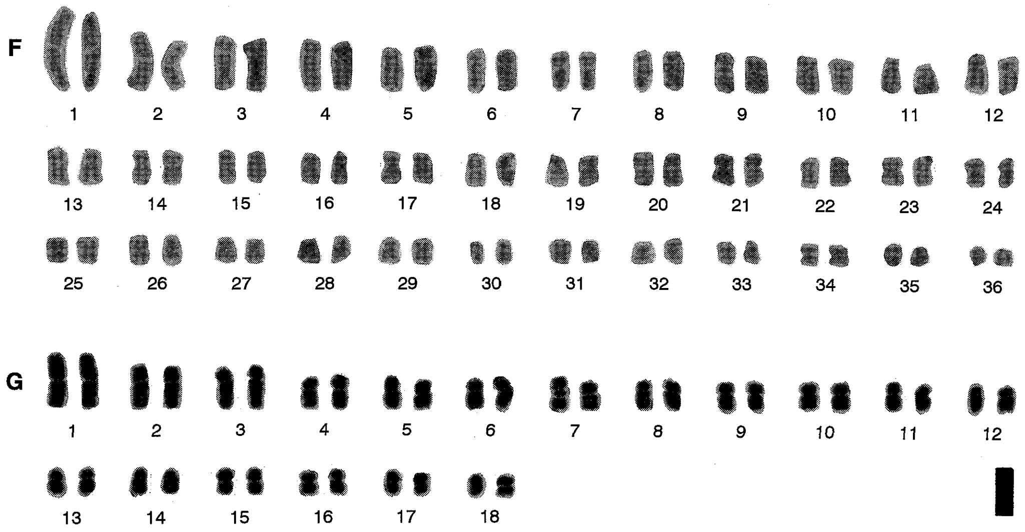


Fig. 4. Serial arrangements of somatic metaphase chromosomes of *Ophiopogon* species. F, *O. japonicus* var. *umbrosus* from Osaka Pref., Yao; G, *O. planiscapus* from Nara Pref., Mt. Sanjohgatake. Bar = 5 μm.

Discussion

The chromosome numbers for *Ophiopogon brevipes*, *O. siamensis* and *O. sylvicola* were first counted in the present study. They are 2n = 36 for the former two and 2n = 54 for the latter one, respectively. The basic chromosome number of x = 18 for the genus *Ophiopogon* were confirmed in the present study, and a triploid with 2n = 54 (for *O. sylvicola*) and a hypotetraploid with 2n = 70 (for *O. japonicus* var. *japonicus*) were first reported from the genus.

In the previous and present studies, chromosome numbers of 26 species of the genus *Ophiopogon* were reported (Table 1). Among the 26 species, 20 species are diploid with 2n = 36. *Ophiopogon clarkei*, *O. sylvicola*, and *O. micranthus* were reported to be hyperdiploid with 2n = 38, triploid with 2n = 54, and hexaploid with 2n = 108, respectively. *Ophiopogon planiscapus* includes both diploids with 2n = 36 and tetraploids with 2n = 72. *Ophiopogon japonicus* seems to be primarily tetraploid with 2n = 72, but also hypotetraploids with 2n = 67, 68 and 70 often occur. Also a diploid with 2n = 36 has been once reported for a plant cultivated in Koishikawa Botanical Gardens, Tokyo, Japan. *Ophiopogon intermedius* appears to be primarily diploid with 2n = 36, but it includes also hypotetraploids with 2n = 68, hexaploids with 2n = 108, and hyperhexaploids with 2n = 112.

Karyotypes of the genus *Ophiopogon* are characterized by one pair of long chromosomes with median centromeres (Oinuma 1946, 1949, Nagamatsu and Noda 1964, 1971, Sharma and Chaudhuri 1964, Hasegawa 1968, Ko et al. 1985, Yang et al. 1990, Ding et al. 1993, the present study). Short chromosomes with secondary constrictions are also observed in the most cases (Oinuma 1946, 1949, Nagamatsu and Noda 1964, 1971, Hasegawa 1968, the present study).

The karyotypes analyzed in the present study, except for those of *O. japonicus*, are categorized into two groups, i.e., Jaburan-

Table 9. Measurements of somatic metaphase chromosomes of *Ophiopogon planiscapus* from Nara Pref., Mt. Sanjohgatake

Pair no.	Length of arms in µm	Total in µm	Size	Arm ratio	Centromere
1	2.7+2.9	5.6	L	1.1	m
	2.7+2.9	5.6	L	1.1	m
2	1.5+2.8	4.3	M	1.9	sm
	1.5+2.7	4.2	M	1.8	sm
3	1.2+2.8	4.0	M	2.3	sm
	1.3+2.9	4.2	M	2.2	sm
4	1.1+1.9	3.0	S	1.7	sm
	1.1+2.0	3.1	S	1.8	sm
5	1.5+1.7	3.2	S	1.1	m
	1.3+1.6	2.9	S	1.2	m
6	1.1+2.0	3.1	S	1.8	sm
	1.0+1.9	2.9	S	1.9	sm
7	1.2+(0.6+1.1)	2.9	S	1.4	m
	1.3+(0.6+1.3)	3.2	S	1.5	m
8	0.9+2.1	3.0	S	2.3	sm
	1.0+2.0	3.0	S	2.0	sm
9	1.1+1.8	2.9	S	1.6	m
	1.1+1.7	2.8	S	1.5	m
10	1.1+1.7	2.8	S	1.5	m
	1.1+1.7	2.8	S	1.5	m
11	1.1+1.7	2.8	S	1.5	m
	1.2+1.5	2.7	S	1.3	m
12	0.9+1.9	2.8	S	2.1	sm
	0.9+1.6	2.5	S	1.8	sm
13	1.0+1.5	2.5	S	1.5	m
	1.0+1.6	2.6	S	1.6	m
14	0.9+1.7	2.6	S	1.9	sm
	0.8+1.6	2.4	S	2.0	sm
15	1.2+1.3	2.5	S	1.1	m
	1.2+1.3	2.5	S	1.1	m
16	1.0+1.2	2.2	S	1.2	m
	1.0+1.2	2.2	S	1.2	m
17	1.0+1.2	2.2	S	1.2	m
	1.0+1.1	2.1	S	1.1	m
18	1.0+1.1	2.1	S	1.1	m
	0.9+1.0	1.9	S	1.1	m

group and Brevipes-group. The Jaburan-group has two pairs of medium-sized chromosomes and comprises karyotypes of *O. jaburan*, *O. planiscapus*, *O. siamensis* and *O. sylvicola*, while the Brevipes-group has three pairs of medium-sized chromosomes and comprises a karyotype of *O. brevipes*. The karyotype of *O. japonicus* has five pairs of medium-sized chromosomes and are categorized into neither group. The karyotypes of *O. bockianus*, *O. bodinieri*, *O. dracaenoides*, *O. griffithii*, *O. marmoratus*, *O. megalanthus*, *O. stenophyllus*, and *O. xylorrhizus*, which were all reported by Yang et al. (1990), are categorized in the Jaburan-group. Accordingly, *Ophiopogon* species

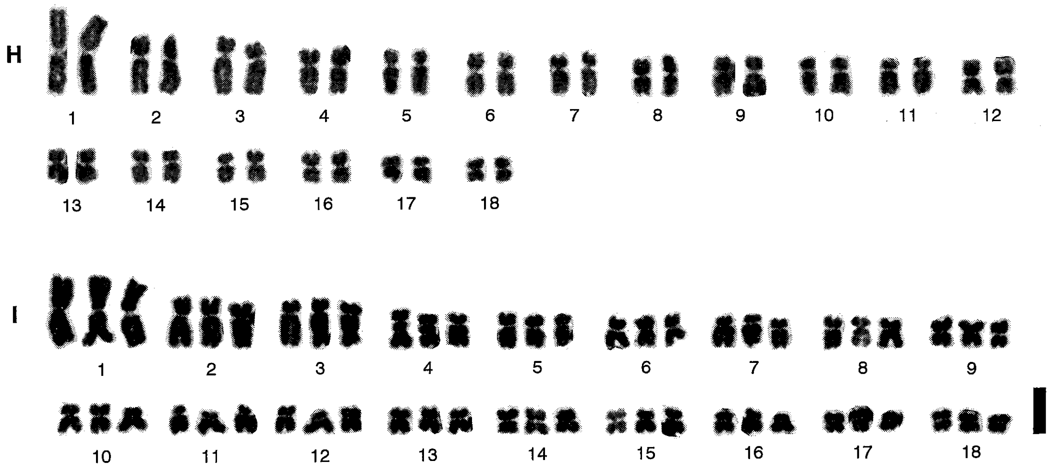


Fig. 5. Serial arrangements of somatic metaphase chromosomes of *Ophiopogon* species. H, *O. siamensis* from Thailand, Doi Inthanon; I, *O. sylvicola* from China, Mt. Wawushan. Bar = 5 μm.

with karyotypes of the Jaburan-group are distributed in warm to cool temperate zones, while *O. brevipes* with a karyotype of the Brevipes-group is distributed in a tropical monsoon zone, although this correlation between karyotypes and distribution patterns should be confirmed by more comprehensive studies.

The triploid *O. sylvicola* examined in the present study is growing very densely along the path in Mt. Wawushan, Sichuan, China. At that place, we have seen neither the flowers nor the seeds yet. Judging from these evidences, the *O. sylvicola* in Mt. Wawushan may be propagating primarily by vegetative reproduction.

Ophiopogon planiscapus from Iwate Pref. to Shizuoka Pref., Japan (except one individual from Koishikawa Botanical Gardens, Tokyo) and also from Kyushu, Japan, were reported to be diploid with 2n = 36 (Sato 1942, Oinuma 1949, Hasegawa 1968). On the other hand, *O. planiscapus* from Kinki District, Japan, in addition to the individual from Koishikawa Botanical Gardens were reported to be tetraploid with 2n = 72 (Sato 1942, Oinuma 1949). In the present study, we counted 2n = 36 for an individual from Nara Pref., Kinki District. Accordingly, not only tetraploids but also a diploid turned out to occur in the Kinki District. Diploids and tetraploids of *O. planiscapus* may not be separated geographically.

Ophiopogon japonicus as well as *O. intermedius* are highly variable in morphology, and several infraspecific taxa are recognized within them. The two species are distributed very widely, respectively, comparing to the other *Ophiopogon* species, i.e., *O. japonicus* from India (?), China to Japan; *O. intermedius* from India to China. Corresponding to the variable morphology and wide distribution, chromosome numbers of the two species are also highly variable as stated above (Table 1). As for karyotypes, tetraploids or hypotetraploids of *O. japonicus* usually have two pairs of long chromosomes with median centromeres (Nagamatsu and Noda 1964, 1971, Sharma and Chaudhuri 1964, Hasegawa 1968, Yang et al. 1990). However, the individuals from Ibaraki, Osaka Pref., Japan (Nagamatsu and

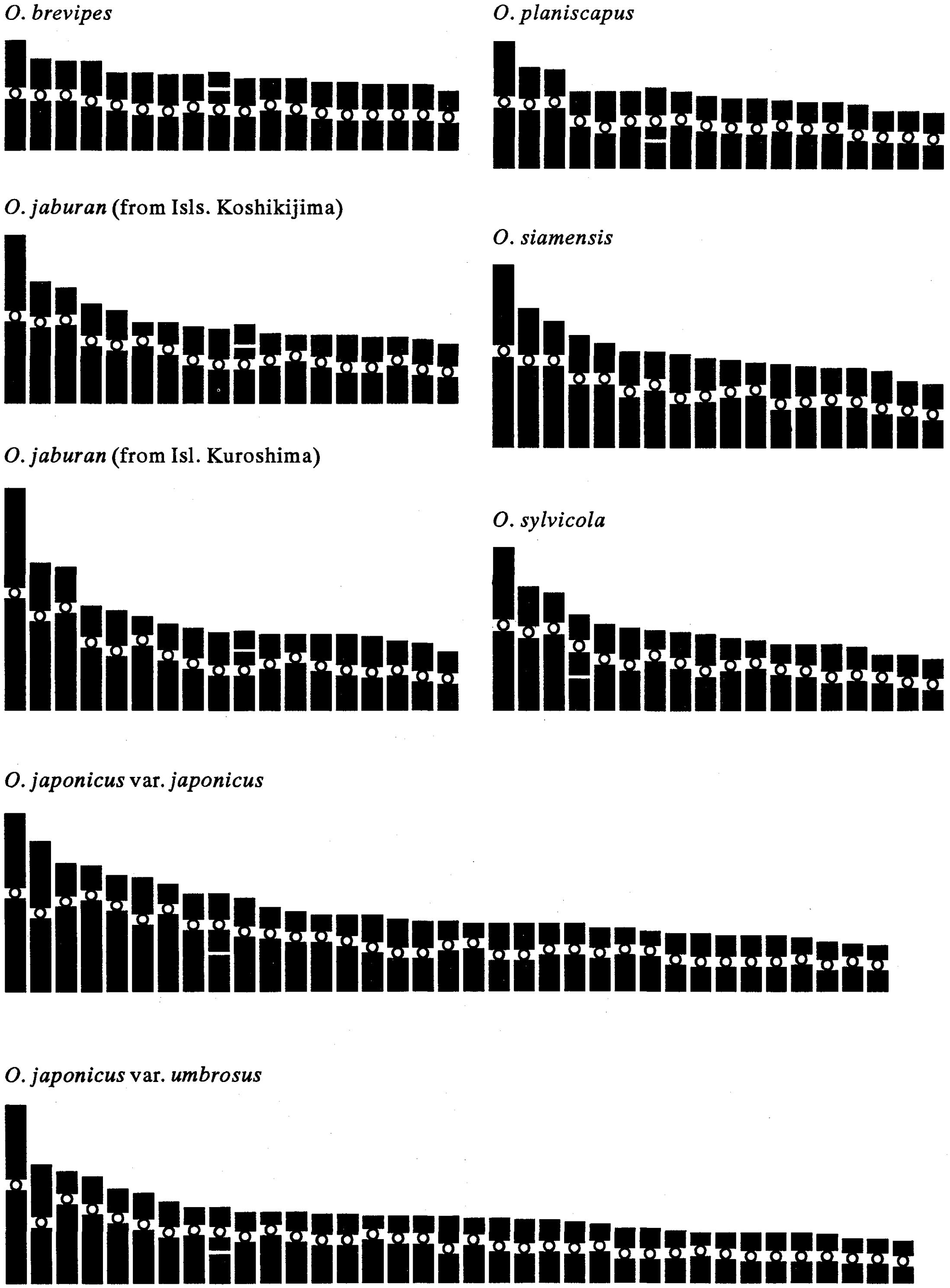
Table 10. Measurements of somatic metaphase chromosomes of *Ophiopogon siamensis* from Thailand, Doi Inthanon

Pair no.	Length of arms in μm	Total in μm	Size	Arm ratio	Centromere
1	4.1+4.4	8.5	L	1.1	m
	3.7+4.2	7.9	L	1.1	m
2	2.3+3.9	6.2	M	1.7	sm
	2.1+3.8	5.9	M	1.8	sm
3	1.6+4.0	5.6	M	2.5	sm
	1.6+3.7	5.3	M	2.3	sm
4	1.7+3.0	4.7	S	1.8	sm
	1.8+3.0	4.8	S	1.7	sm
5	1.4+2.9	4.3	S	2.1	sm
	1.4+3.0	4.4	S	2.1	sm
6	1.6+2.3	3.9	S	1.4	m
	1.6+2.4	4.0	S	1.5	m
7	1.4+2.6	4.0	S	1.9	sm
	1.2+2.7	3.9	S	2.3	sm
8	1.8+2.0	3.8	S	1.1	m
	1.8+2.2	4.0	S	1.2	m
9	1.6+2.2	3.8	S	1.4	m
	1.4+2.1	3.5	S	1.5	m
10	1.1+2.3	3.4	S	2.1	sm
	1.2+2.4	3.6	S	2.0	sm
11	0.9+2.5	3.4	S	2.8	sm
	1.0+2.4	3.4	S	2.4	sm
12	1.6+1.8	3.4	S	1.1	m
	1.5+1.8	3.3	S	1.2	m
13	1.3+1.9	3.2	S	1.5	m
	1.4+1.8	3.2	S	1.3	m
14	1.2+2.0	3.2	S	1.7	sm
	1.2+2.0	3.2	S	1.7	sm
15	1.2+1.9	3.1	S	1.6	m
	1.3+1.9	3.2	S	1.5	m
16	1.4+1.6	3.0	S	1.1	m
	1.5+1.6	3.1	S	1.1	m
17	1.1+1.4	2.5	S	1.3	m
	1.0+1.5	2.5	S	1.5	m
18	1.1+1.2	2.3	S	1.1	m
	1.2+1.3	2.5	S	1.1	m

Noda 1964) and from Mt. Daedunsan, Kaenamgun and Haga, Cheju Isl., Korea (Ko et al. 1985) have only one pair of long metacentric chromosomes. In the present data of ours, an individual from Minoo, Osaka Pref. has two pairs of the long metacentric chromosomes, while an individual from Yao, Osaka Pref. has only one pair of the long metacentric chromosomes. Accordingly, it was confirmed by the present study that *O. japonicus* is variable not only in chromosome number but also in karyotype.

Table 11. Measurements of somatic metaphase chromosomes of *Ophiopogon sylvicola* from China, Mt. Wawushan

Pair no.	Length of arms in µm	Total in µm	Size	Arm ratio	Centromere
1	3.5+3.9	7.4	L	1.1	m
	3.5+3.9	7.4	L	1.1	m
	3.4+3.6	7.0	L	1.1	m
2	2.0+3.4	5.4	M	1.7	sm
	2.0+3.6	5.6	M	1.8	sm
	1.6+3.4	5.0	M	2.1	sm
3	1.4+3.6	5.0	M	2.6	sm
	1.4+3.9	5.3	M	2.8	sm
	1.3+3.7	5.0	M	2.8	sm
4	1.2+(1.1+1.8)	4.1	S	2.4	sm
	1.2+(1.1+1.4)	3.7	S	2.1	sm
	1.2+(1.2+1.3)	3.7	S	2.1	sm
5	1.6+2.3	3.9	S	1.4	m
	1.3+2.1	3.4	S	1.6	m
	1.3+2.1	3.4	S	1.6	m
6	1.4+1.9	3.3	S	1.4	m
	1.5+1.9	3.4	S	1.3	m
	1.6+1.9	3.5	S	1.2	m
7	0.9+2.4	3.3	S	2.7	sm
	0.9+2.5	3.4	S	2.8	sm
	1.0+2.2	3.2	S	2.2	sm
8	1.2+2.1	3.3	S	1.8	sm
	1.2+2.0	3.2	S	1.7	sm
	1.2+2.0	3.2	S	1.7	sm
9	1.6+1.7	3.3	S	1.1	m
	1.5+1.6	3.1	S	1.1	m
	1.4+1.5	2.9	S	1.1	m
10	1.1+2.0	3.1	S	1.8	sm
	1.0+1.7	2.7	S	1.7	sm
	1.0+1.9	2.9	S	1.9	sm
11	0.8+2.1	2.9	S	2.6	sm
	0.8+1.9	2.7	S	2.4	sm
	0.9+2.1	3.0	S	2.3	sm
12	1.0+1.7	2.7	S	1.7	sm
	0.8+1.6	2.4	S	2.0	sm
	1.0+1.7	2.7	S	1.7	sm
13	1.0+1.6	2.6	S	1.6	m
	1.0+1.5	2.5	S	1.5	m
	1.0+1.6	2.6	S	1.6	m
14	1.4+1.4	2.8	S	1.0	m
	1.3+1.3	2.6	S	1.0	m
	1.3+1.3	2.6	S	1.0	m
15	1.2+1.4	2.6	S	1.2	m
	1.1+1.5	2.6	S	1.4	m
	1.0+1.4	2.4	S	1.4	m
16	0.9+1.4	2.3	S	1.6	m
	0.8+1.3	2.1	S	1.6	m
	0.8+1.3	2.1	S	1.6	m
17	1.0+1.1	2.1	S	1.1	m
	1.0+1.2	2.2	S	1.2	m
	1.0+1.1	2.1	S	1.1	m
18	0.9+1.0	1.9	S	1.1	m
	0.9+1.0	1.9	S	1.1	m
	0.9+1.0	1.9	S	1.1	m



O. brevipes

O. planiscapus

O. jaburan (from Isls. Koshikijima)

O. siamensis

O. jaburan (from Isl. Kuroshima)

O. sylvicola

O. japonicus var. *japonicus*

O. japonicus var. *umbrosus*

Fig. 6. Karyograms showing the somatic metaphase karyotypes of *Ophiopogon* species. Each idiogram shows a homologous chromosome pair.

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山下　純，田村　実：ジャノヒゲ属（スズラン科ジャノヒゲ連）6種の核型分析

本研究では，ジャノヒゲ（大阪府箕面市産），ナガバジャノヒゲ（大阪府八尾市産），オオバジャノヒゲ（奈良県山上ヶ岳産），ノシラン（鹿児島県甑島諸島と黒島産），*O. sylvicola*（中国四川省瓦屋山産），*O. brevipes*（タイ国ステップ山産），*O. siamensis*（タイ国インタノン山産）の核型分析を行った．*O. sylvicola*, *O. brevipes*, *O. siamensis* の染色体の観察は今回が初めてである．その結果，オオバジャノヒゲ，ノシラン，*O. brevipes*, *O. siamensis* は2n = 36の2倍体，*O. sylvicola* は2n = 54の3倍体，ジャノヒゲは2n = 70の低4倍体，ナガバジャノヒゲは2n = 72の4倍体であった．これらの内，2n = 54の3倍体と2n = 70の低4倍体の報告はジャノヒゲ属で初めてである．今回分析した核型は，ジャノヒゲとナガバジャノヒゲのものを除いて，中型染色体を2対もつJaburan-groupと3対もつBrevipes-groupに分けられる．オオバジャノヒゲ，ノシラン，*O. sylvicola*, *O. siamensis* はJaburan-groupの核型をもち，暖温帯域～冷温帯域に分布する．*O. brevipes* はBrevipes-groupの核型をもち，熱帯モンスーン域に分布する．（大阪市立大学大学院理学研究科附属植物園）